Results From the First Two Flights of the Static Computer Memory Integrity Testing (SCIMT) Experiment

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ABSTRACT

This paper details the scientific objectives, experiment design, data collection method, and post flight analysis following the first two flights of the Static Computer Memory Integrity Testing (SCMIT) experiment. SCMIT is designed to detect soft-event upsets in passive magnetic memory. A soft-event upset is a change in the logic state of active or passive forms of magnetic memory, commonly referred to as a "Bitflip" (see Fig. 1). In its mildest form a soft-event upset can cause software exceptions, unexpected events, start spacecraft safeing (ending data collection) or corrupted fault protection and error recovery capabilities (see Fig 1.1). In it's most sever form loss of mission or spacecraft can occur. Analysis after the first flight (in 1991 during STS-40) identified possible soft-event upsets to 25% of the experiment detectors. Post flight analysis after the second flight (in 1997 on STS-87) failed to find any evidence of soft-event upsets. The SCMIT experiment is currently scheduled for a third flight in December 1999 on STS-101.

INTRODUCTION

Over the years several different spacecraft have suffered soft-event upsets (bit-flips) of their onboard memory. The most famous instance occurred in 1986 when the Voyager 2 spacecraft was encountering the planet Uranus. The spacecraft suffered soft-event upsets to its Flight Data Subsystem (FDS) during far-encounter. This caused a loss of guidance and control for several hours that resulted in the spacecraft pointing its instruments out into deep space away from the planet. Similar events have impacted the Galileo Jupiter Orbiter Command and Data Subsystem (CDS) during encounters with the moons Io and Europe.

Today as larger, more complicated systems are developed and planned (International Space Station, human missions back to the Moon and on to Mars) the possibility of soft-event upsets affecting static memory is becoming a concern. Large systems should not relay on mass uplinks for reloading embedded command and data handling, attitude control and related subsystems. A safer approach is to carry back-ups of the embedded flight software on static memory (* note though not related to a soft-event upset, but significant coding errors the Magellan spacecraft required each block of its flight software be uplinked from Earth overwriting privileged memory shortly after Venus orbit insertion. This significantly raised the risk of permanently losing the spacecraft after the initial recovery).

SCIENTIFIC OBJECTIVES

The objectives of this experiment are:

- Observe Soft-event upsets
- Determine the frequency of soft-event upsets
- Determine the characteristics of soft-event upsets
- Determine the possible effectiveness of different types of shielding material
- Evaluate the possibility of using static memory as a type of passive detectors

EXPERIMENT

General

The experiment uses a number of commercial floppy disks. Each disk was loaded with a text file/bit-map identical in size and format (see Fig.2). This method made it simple to determine when a soft event upset had occurred by observing a change in the logic state (character representation) of any area on the bit maps during post flight analysis (see Fig.3). Each disk contained one large text file/bitmap

STS-40

For the first flight as part of GAS payload G-616, ten disks were inserted into each of four storage containers (see Fig. 4). Several of the disks were covered in one of three types of shielding material:

- Normal anti-static nylon
- Aluminized Mylar mesh
- Field dispersing (electrically neutral) nylon

STS-87

For the second flight as part of GAS payload G-036 five disks were inserted into a one storage container and three disks were each covered with one of the three types of shielding material (see Fig. 5).

Procedure

General

The experiment was constructed by:

- Developing a standard text file/bitmap
- Copying an identical standard text file/bitmap on each disk
- Testing to assure the integrity of each text file/bitmap
- Covering a number of the disk with one of the three types of shielding material
- Inserting disks into storage containers
- Integrating the disks and storage containers into the GAS canister

STS-40

For the first flight the experiment was integrated into the GAS canister in June of 1990. The experiment remained on the GAS Bridge assembly until after landing in June 1991. The experiment remained in orbit for 9 days. Post flight recovery and analysis took place within 30 days of landing.

STS-87

During the second flight SCMIT was integrated in the GAS canister and flown as part of STS-87. The experiment remained in orbit for 16 days. Floppy disks that had not shown any affects (no evidence of soft-event upsets, text file/bitmap intact) from the STS-40 flight were re-flown during STS-87. Post flight recovery and analysis took place within 30 days of landing.

POST FLIGHT ANALYSIS

General

After each flight every disk was analyzed for evidence of soft-event upsets. Each text file bit was viewed/compared and verified.

STS-40

During the first flight, single event, soft event upsets were not observed. However ten disks in one of the four storage containers did exhibit characteristics that could be attributed to a massive number of soft-event upsets. Preflight testing was conducted that verified the integrity of each text file/bitmap before integration and launch. Preflight tests should have captured the types of errors discovered during post flight analysis if these errors had occurred during experiment development and construction. The disks that exhibited these characteristics where not shield during the flight. It is important to note the experiment was stored for one year on the GAS Bridge assembly prior to launch in June of 1991.

STS-87

During the second flight, single event, soft event upsets were not observed. In addition the massive errors observed in 10 disks from the first flight were not present in any shielded or unshielded disk re-flown during STS-87.

CONCLUSIONS

General

The data supports an anomalous event occurring to 10 disks flown on STS-40. Additional exposure (16 days on orbit) on STS-87 of five disks did not reproduce the types of errors observed during STS-40. Storage of the experiment on the GAS Bridge for one year prior to the launch of STS-40 may have contributed to the observed errors. However, 30 additional disks in 3 other containers did not suffer any affect. The third flight on STS-101 will repeat the experiment has flown during STS-87.

STS-40

The types of soft-event upsets anticipated prior to flight were not observed. However a massive number of changes were observed in the logic state of 10 disks from a single container (25% of the total number). This indicates the possibility that soft-event upsets or a similar type of event occurred. It is also possible that while the experiment was stored on the GAS Bridge (1 year prior to flight) it was exposed to a magnet field or high-energy event could have created the type of changes observed. However it is worth noting 30 other disks divided among 3 different containers did not show any affect from the flight (including pre and post). It is also possible the errors occurred during construction of the experiment. However this is considered unlikely.

STS-87

During the second flight exposure to the environment of low earth orbit increased to 16 days.
A smaller number of disks served as detectors and all five were contained in a single box.
Three of the five disks were covered by one of the three types of shielding material.
Soft-event upsets were not observed in any disk. In addition the type of massive errors for the first flight were not observed. This is contra to the result of the first experiment. The third flight on STS-101 will repeat the experiment has flown during STS-87.

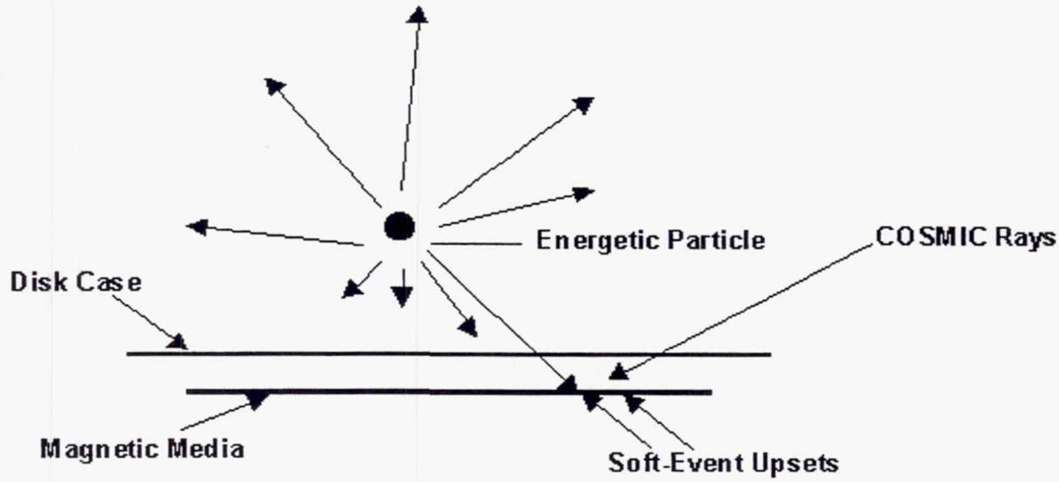

Figure 1. Soft-Event Upsets

```
type Acquisition_Data_type is record
   Total_Exception_Counter    : UAS_MDM_types.Byte_t;
   Spare                      : boolean;
   Ada_Exception_Counter      : Ada_Exception_Counter_type;
   Spare2                     : boolean;
   Ada_Exception_per_CSC      : Ada_Exception_per_CSC_type;
 end record;

 for Acquisition_Data_type use record at mod 2;
   Total_Exception_Counter    at 0 range 0..7;
   Spare                      at 0 range 8..15;
   Ada_Exception_Counter      at 2 range 0..55;
   Spare2                     at 9 range 0..7;
   Ada_Exception_per_CSC      at 10 range 0..
     (Scheduler_Objects.CSC_Type'POS(Scheduler_Objects.CSC_Type'LAST) +1)
      * Scheduler_Objects.CSC_Type'SIZE - 1;
 end record;
```

Example of uncorrupted Code

```
type Acquisition_Data_type is record
   Total_Exception_Counter    : UAS_MDM_types.Byte_t;
   Spare                      : )(*%^ean;
   Ada_Exception_Counter      : Ada_Exception_Counter_type;
   Spare2                     : boolean;
   Ada_Exception_per_CSC      : Ada_Exception_per_CSC_type;
 end record;

 for Acquisitionsereaqsz_Data_type use record at mod 2;
   Total_5642356bxception_Counter    at 0 range 0..7;
   Spare                      at 0 range 8..15;
   Ada_Exception_Counter      at y7nthdftrs 0..7;
   Ada_Exc*&Rion_per_CSC      at 10 range 0..
     (Scheduler_54wdfcy.CSC_)_(*%*^%6555555fdgsc mh7778@%$%^%%$%@#
_Objects.CSC_Type'LAST) +1)
      * Scheduler_Objects.CSC_Type'SIZE - 1;
 end record;
```

Example of Code Impacted by Soft-Event Upsets

Fig 1.1 Flight Software Impacted by Soft-Event Upsets

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Figure 2. Sample of a Text File/Bitmap

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11111111000011we5431sds111111111111111111111111111111111111111111111111111111111
1111111111111111sd11111111111111111111111111111111111111111111111111111111111111
1111111111111111111111111111111111111111111111111111111111111111556432sd10011111
11111111111111111111111111111111111111111111111111111111111111111111111101001111
11111111111111111111111111111111111111111111111111111111111111111111110011000111
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```

Figure. 3 Example of Soft-Event Upsets anticipated before flight

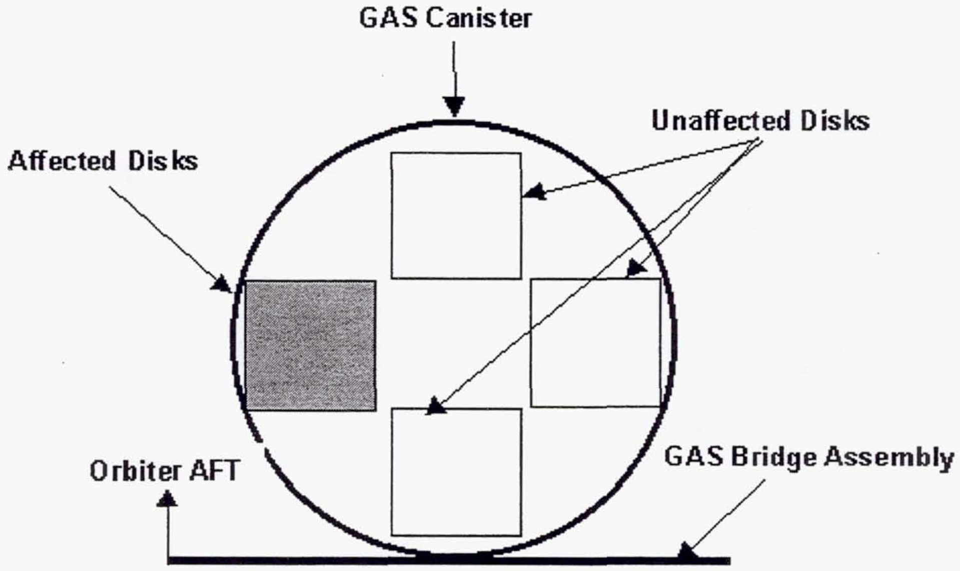


Figure 4. Position of SCMIT Experiment in GAS Canister - STS-40

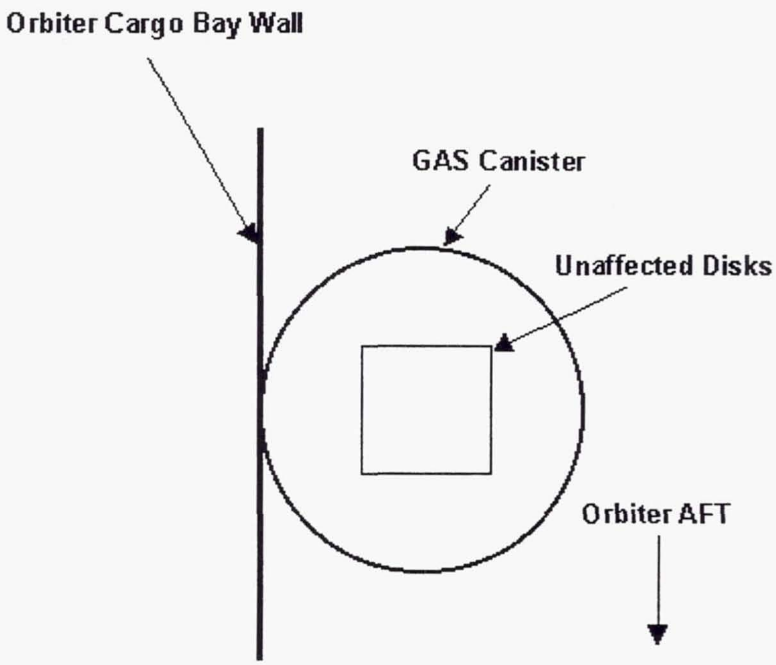
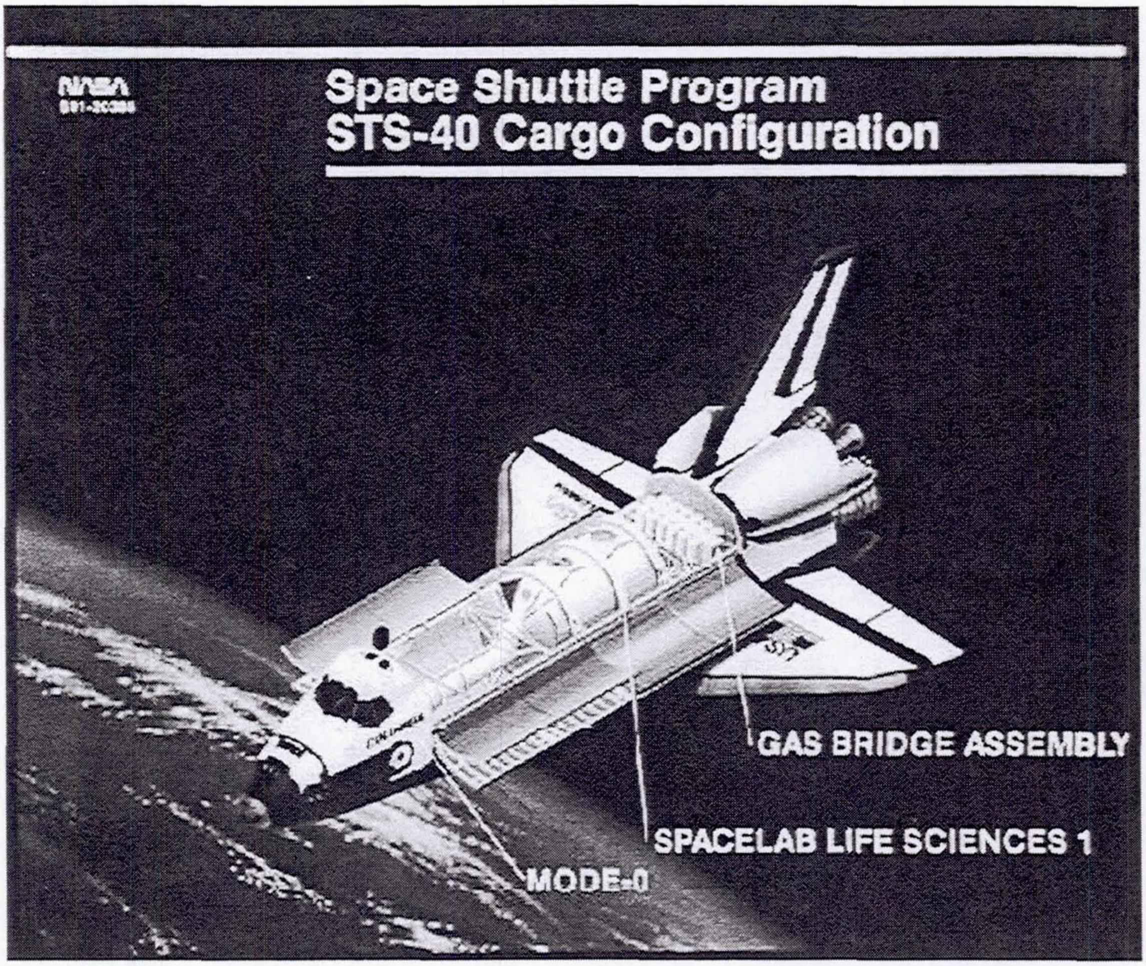
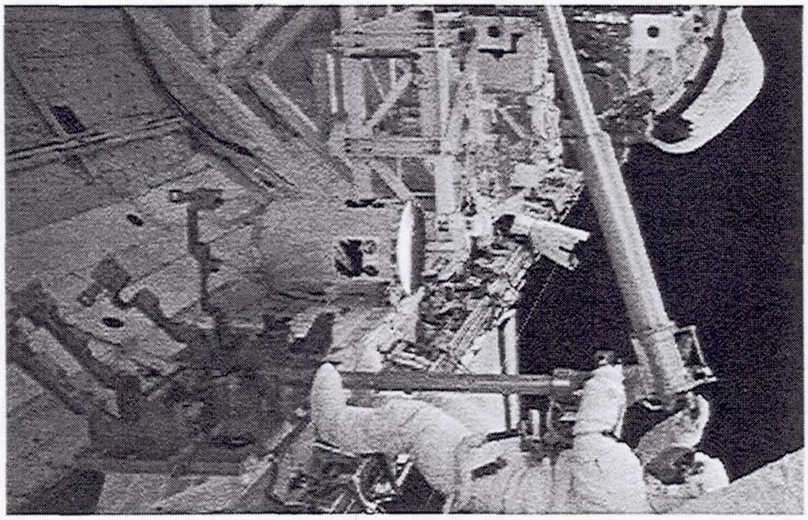


Figure 5. Position of SCMIT Experiment in GAS Canister - STS-87



GAS Bridge Assembly STS-40



SCMIT in G-037 on STS-87